# STUDIES OF CONTAINER SIZE AND TYPE FOR PEPPER (*Capsicum annuum* L.) TRANSPLANT PRODUCTION

by

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## INTRODUCTION

Small seedling transplants grown in a small round, or square container cell are often called "plugs". Plug production is a relatively new method of plant production compared to traditional methods and has been in existence for about 15 years. In the beginning most plugs were annuals such as petunias, begonias, and impatiens. Later, vegetable plugs began to be produced. Vegetable plugs produced today include bell pepper, broccoli, brussels sprouts, cabbage, Chinese cabbage, lettuce, and tomato (8, 12, 23, 28, 44).

Until recently, most vegetable plug research was conducted on crops such as tomato (12, 24, 43), broccoli (8), cauliflower (8), Chinese cabbage (23), and lettuce (23). Specific studies on bell peppers (<u>Capsicum</u> <u>annuum</u> L.) have recently been reported in the literature (7, 14, 27, 32, 44). Private companies, on the other hand, have been growing and marketing bell pepper plugs for many years (21, Dick Bostdorff, 1988 Speedling Inc., Sun City, FL., personnel communication).

There are two main reasons for recent emphasis on research on bell pepper containers. First, growers of peppers are looking for more profitable ways to grow peppers (7, 44), and second, bell peppers are increasing in popularity (4).

Growers want to grow pepper plants from transplants

Growers want to grow pepper plants from transplants that are economical, produce earlier and greater total yields, and have good fruit shape and size (7, 27, 32, 44). These factors have been shown to be affected by plug sizes, age of transplants and temperature. (7, 8, 14, 27, 32, 43, 44).

Increased popularity of peppers has probably resulted from increased number of salad bars at eating establishments, greater emphasis on eating fresh vegetables, pizzas, and public awareness of the nutrive value of vegetables (4). Pepper popularity in developing countries and tropical areas has caused interest at the Asian Vegetable Research and Development Centers intensive crop improvement program (4). Bell peppers have significant amounts of vitamin A and C, can be used in fresh or processed form, tend to have a longer shelf life and transport better than other vegetables like tomato (4).

Plugs or small transplant containers have been a growing innovation of the 1980's. Between 1982 and 1984 alone, plugs produced nationally by specialized propagation and sold to greenhouses for finishing increased 700%, indicating that plugs are a trend for the future for greenhouse growers and the bedding plant industry. (3)

The bedding plant industry and commercial growers, like any other business, depend on innovative ideas for future expansion. This will continue with new plant varieties,

innovative growing and marketing programs, and new technology accomplished by the technical advances made by plug production or single cell plant production (5, 11, 18, 20, 26).

## OBJECTIVES

The objectives of this study were to determine the effects of container sizes and holding temperatures on yield, fruit shape, appearance, and mechanical transplant survivability of direct transplanted bell pepper.

## LITERATURE REVIEW

Before the advent of plug trays, growers used containers such as banana leaves (25), peat (41), manure (15), clay (41), and plastic pots (41), and plastic flats for plant production. Manure, peat, and clay pots can create problems in management since they are made of porous materials which allow containers to dry out rapidly (15, 41). These containers also may take up valuable greenhouse space (9). Many growers have switched to the plug type containers to alleviate these problems (21).

Some growers purchase plugs from other growers. Buying grown plugs permits the grower to have an extended variety of plants and to schedule crops efficiently because valuable greenhouse space is not tied up for producing seedling plants. A bedding plant producer who purchases plugs finds that 1/2 to 3/4 of the job is done for him (11).

Some growers purchase plugs to cover their own germination losses (3). Seed germination is one of the major obstacles facing the plug grower. The success or failure of their germinating methods usually depends on the ability to achieve uniform control of environmental conditions. If optimum levels of moisture, temperature, and light are not achieved, difficulties in obtaining a high germination percentage can be encountered. Germination can be increased by using controlled environment rooms, "sweat

chambers" and greenhouses, or other structures with intermittent mist (3, 11, 18, 19, 20, 21, 22).

There are several types of flats, or trays used in plug production (8, 21, 24). Flats may contain from 50 to 648 cells per flat. The cells can be round or square (21). The flats are made of plastic or polystyrene. One of the most popular plug flats is the Todd (Speedling) plug flat (8, 43, 44). Speedling (Sun City, Fla.) has become a major supplier of plugs world wide (28, 44). They produce ornamental plugs, but specialize in vegetable plugs (28). In 1988, they sold 1.2 billion vegetable and ornamental plugs (Dick Bostdorff, 1988. Speedling Inc., Sun City, Fla., personal communication).

The flats used by Speedling are made of expandable polystyrene and are produced in various sizes (Table 1) (8,44). The cells resemble a square, inverted pyramid (8). This design allows the roots to grow downward orienting them for a positive grow off, minimizing root binding, and allowing air to prune the roots (3). Plants do not become root bound to each other as in flats, since each plant grows in its own space. Due to the shape and growth of the plants in the cells, they are easily removed form the cell (11).

There is minimal transplant shock because seedlings are unitized, each with its own root ball. Once the plugs are planted, they are primed for quick rooting in and take off

(3, 8, 11, 18).

Better quality plants are obtained with flats that contain a few but larger cells, since competition between adjacent seedlings is reduced (8, 21, 23, 43, 44). Seedlings do not seem to stretch as quickly in plug trays compared to seedling flats due to more uniform spacing in the plug flat (3). If a grower gets behind schedule the plug flat can set without worry about misshaped plants (11). Petunia and impatiens plug seedlings can be held up to 4 weeks at temperatures of 12$^{o}$ - 15$^{o}$C. It has been observed that irreversible stunting and delayed flowering occur with plugs held at those temperatures for longer than 4 weeks (19).

Different sizes of containers have shown they can influence plant development through physical construction - water - soil interaction (15). Although both round and square plug flats can be used successfully, the distribution of moisture may be more uniform in square plug flats than to round plug flats (21).

Koranski (22) found that one of the most important aspects of a plug tray is its depth in relation to the air porosity of the medium in the tray cells. A 6" pot containing peat and vermiculite will have an air porosity of approximately 20% of the medium, resulting in sufficient drainage. The same medium in a 406 cell plug tray would

have an air porosity of approximately 1-2% with the difference related to depth of the container. At least a 2 inch column of soil is needed to drain water and prevent $O_2$ deficiency. Many growers are trying to germinate with 0% porosity in small plug cells.

The choice of plug flat depends on profitable return or investment in seed, space, time (21), field seed bed conditions, and cost of transplants (8).

Transplants are preferred over direct seeding, especially in areas where the growing season is relatively short (8, 43, 44). Most of the northern latitude states fall into this area. Minnesota growers use transplants for growing cole crops (8). In Michigan, where the main fresh market crop is tomato, transplants are used extensively in tomato production (43). The majority of processing tomato acreage in Ohio is planted using transplants (24). Bell pepper is a major fresh market and processing crop in Kentucky and Massachusetts. Kentucky growers use southern grown transplants due to the short growing season in Kentucky (44).

Growers are using plug type transplants instead of bareroot transplants because of less transplant shock with plug transplants (43). Michigan growers buy most of their bareroot transplants from southern growers. The majority of the plants are field grown and suffer severe transplant shock when transplanted into the field (43). Transplants

are also preferred over direct seeding because the earlier a crop can be produced, the higher the market price it will usually command. (8) Good quality transplants produce better stands, earlier yields, and better total yields, plant growth, and fruit size then direct seeded plants (12, 15, 23, 43, 44).

Numerous cultural practices are known to affect tomato and pepper transplant quality and subsequent fruit yield in the field (43, 44). Tomato fruit yields should increase as the space per plant during seeding growth increase in the greenhouse. Plants grown in larger root cells tend to have more leaves, suffer less transplant shock, and produce earlier than do small cells. This is probably due to increased root development and less root binding in the larger cell, which promotes early establishment in the soil (12, 15, 43, 44). Pepper plants grown in containers that reduced root damage and loss during transplanting, grew faster after being set in the field and produced greater earlier yields than bareroot plants (44).

The size of the cells and the environment in which the transplants are produced have been reported to affect the growth and yield of tomato (12, 15, 43), cabbage (12), celery (16), Chinese cabbage (23), lettuce (23), and pepper (44) in the field. Weston and Zandstra (43) reported that tomato transplants grown in larger cell flats produced

earlier yields than plants grown in smaller cells. Statistically, the larger cell sizes did not produce more total yield, but they noted that plants grown in 175-size cells produced up to 25% more total yield than the plants grown in the 080A cell. They also concluded that yields also depend on the proper establishment of the initial stand.

Weston (44) reported that pepper transplants grown in larger cells produced greater, earlier yields than small cells, but not greater total yields. It was also shown that transplants grown in the 175 cell had greater height, leaf area, and dry weight at field setting and produced earlier fruit yield than did plants grown in smaller cells. Plants grown in the 175 cell produced a 37% greater early yield than 080A cell. It was also shown that cell surface area and volume were highly and positively correlated with pepper early yielding ability.

Latimer (27) reported that plants grown in 100A flats performed better than those from GS 135 flats in early but not total yield. Early yield of plants grown in 080A flats were significantly less than that of plants from the other flats but there were no differences in total yield. The 080A had the best root to shoot ratio but needed a better seedbed to reestablish root growth. The 175 flat was the best overall flat.

McGrady (32) reported that older pepper transplants

grown in larger cells produced a higher early and total yield than young transplants from small cells. When testing another variety of pepper, he found that the larger cell size increased the early but not total yield.

Dufault and Waters (8) reported that container volumes, width, and depth and density did not affect marketable yields, earliness, length of harvest season of broccoli or cauliflower. They indicate that comparisons between different transplant systems can be difficult because of differences in container size, shape, crop genotype, and the environment in which they are grown.

Cost of transplants and plants per hectare depend on cell size (Table 1). Small cells take up less space in the greenhouse which makes them less expensive than larger cells (8, 43). Even though the establishment cost is lower for small cells, other problems can develop with the smaller transplant which can minimize their economic advantage, thus affecting their suitability (8).

Smaller transplants are more dependent on soil texture and seedbed condition than larger transplants. Lighter soils don't form large clods like heavy soils. This provides better root contact between the soil and the transplant media at transplanting, reducing the risk of transplant desiccation. In heavy soils, small plugs fail to make good root contact since large air spaces are formed. To reduce

desiccation and stand reduction, larger plugs are recommended (8, 44).

The increased cost of growing transplants in larger cells in the greenhouse may be overcome by increased early and total yields (12, 13, 43, 44). Market prices must also be taken into account (12 44). The grower must therefore consider seedbed conditions and transplant costs when deciding which cell size to use (8).

The importance of container volume, until recently, has been ignored in studies, even though root restriction is known to definitly affect the growth and development of many plants (8, 12, 36, 39, 41). Dwarf plants have resulted from reduced soil volume (36). Larger plants from less restricted cells produce larger total yields in peppers (34). Small containers tend to develop plants that have short, densely branched root systems, where as plants grown in larger containers develop root systems that have long taproots with little branching. This may affect the total plant growth since gibberellins and cytokinins are found in roots and providing an important source of growth substances in the plant (36). Reducing the amount of gibberellins and cytokinins transported from the roots may be one reason for the retarded shoot growth observed in root restricted plants (36). Reduction in shoot dry weight, length, internode elongation, and size and number of laterals, have also been attributed to root restriction. Vegetative effects such as

reduction in leaf area, leaf number, leaf dry weight, total number and fresh and dry weight of mature fruits, are also affected by root restriction (36).

Some changes in plants grown in root confined conditions such as small leaf area, thicker stem, leaves, and roots, and reduced shoot and root growth, may result from drought stress. Other researchers believe that growth substances (cytokinins or gibberellins) are the reason for smaller, dwarf plants, not drought stress (36). Reduction in growth can also result from decreased root hairs and lateral initiation which can hinder water absorption (36). Age of transplants at field setting are known to affect maturity and yield of plants (23, 31, 44). Since Chinese cabbage yields were not affected by transplant age within a 3 to 6 week old range, it was not necessary to grown seedlings beyond the 3 week period. It was noted that the 3 to 6 week growing period gave producers of Chinese cabbage timing and scheduling flexibility in seedling production (23).

Nicklow (34) reported that relatively young transplants of tomato and pepper were more desirable for large total yields than older plants. For earlier yields it was suggested to plant older transplants. However, plants with open flowers should be avoided because of the detrimental effects of early fruit set. Plants that had no buds or buds

only at transplanting produced larger early and total yields and larger fruit size than plants with open flowers or developing fruit.

McCraw and Greig (31) reported 11-week old pepper transplants produced more fruit than 8-week old transplants. When the transplants are 15 cm tall and planted on about May 15, the plants should be producing by late July (75-80 days after transplant) in Kansas under normal growing conditions. Weston (44) reported that 60-day old seedlings transplanted into the field produced early yields up to 70% greater than younger seedlings; however, total yields were not significantly affected.

Studies show that N nutrition influences the yield and growth of peppers and other vegetable plants (26, 13, 33, 40, 41, 43). Seedlings of tomato and pepper that have been adequately fertilized with N,P,K, show greater early and total yields (16, 17, 33, 43, 44). It was reported that when N fertilization was increased in pepper seedlings (up to 4% leaf N) it improved both transplant performance and gave higher yields (16, 29, 44). Nicklow (34) reported that pepper plants produced the highest total yields when the plants had dark green leaves and medium to brittle stems at transplanting.

There have been conflicting reports on the effect of N on pepper plants. Some reports show that N has no effect on pepper yields, while others show excessive N can reduce

yields. High levels of N have been shown to enhance fruit set in peppers (16). Speedling Inc. (Sun City, Fla) fertilized their tomato transplants with a low concentration of N (30 ppm) and withheld nutrients during the last few weeks of production to harden the plants. Since this resulted in small transplants and reduced early yields, Speedling has since changed their fertilizing practices to correct the problem. When compared to larger, more vigorous plants, the small, slower growing transplants produced the same total yield (43). Vandemark and Splittstoesser (41) reported that small plant size was the result of limited amount of nutrient and soil volume available for root growth.

Bell pepper is known to be a crop that is sensitive to temperature extremes (14). Temperature affects growth, flowering, fertilization, fruit set, shape, weight, length, pericarp thickness, and number of seeds per fruit (1, 2, 14, 16, 29, 35, 39, 42). Temperatures for growing peppers range from 22 - 29$^{o}$C day to 15 - 24$^{o}$C night (1, 2, 30, 35, 37, 39, 40, 43, 44). Night temperatures have been shown to affect fruit set more than day temperatures (39, 40, 42). Fruit set is highest when night temperatures are between 10 and 16$^{o}$C (39, 40, 42). Low night temperatures promote fruit set but at the same time have prevented normal fruit growth and produced fruits with few or no seeds (35, 37, 39). Low

day temperatures (22°C) also increased the number of seeds per fruit (39). At temperatures between 24 and 37°C fruit set was prevented and most buds dropped before flowers opened (14, 39). Removing fruit before night temperatures reached 24°C, increased the percent of fruit set (39). Night temperature has affected fruit set on many cultivars of pepper. One must also consider the combined effects of night temperatures and other factors such as day temperatures and length, radiation intensity, plant age, and size (29, 39).

Temperature is known to affect the sexes of flowers in many plant species. High temperatures enhance male flowers whereas low temperatures enhance female flowers (35). Low and high night temperatures result in production of nonviable pollen. At low temperatures (8-10°C), developing flowers produce stigmas that are elongated and grow taller than stamens, causing self pollination difficulties (37). Plants grown at 18°C day and 15°C night temperatures produced seedless fruit when flowers were left to self pollinate. This was probably due to abnormal pollination (35, 39). Flowers from nonpollinated plants grown at 23°C day and 18°C night and 28°C day and 23° night temperatures abcised (35, 37). High temperatures after anthesis have been known to abort non-fertile flowers (37). Plants grown at 15°C and 21°C night temperatures produce the greatest number of flowers per plant (42).

Temperatures during initial stages of flower development affect the final size and shape of pepper fruits (1, 2, 14, 37, 39, 42). Flowers developing at high night temperatures (18-21$^{o}$C) produce good shaped and elongated fruit (37). Plants grown in high night temperatures up to anthesis and low (8-10$^{o}$C) temperatures afterwards, produced fruits that had high length/diameter ratios. Smaller length/diameter ratios are produced when plants grow at low temperatures before and after anthesis. At low temperatures, when flowers are being developed, small oblate fruits are produced. If high temperatures after anthesis occur, fruit shape will not change (37). Blocky, four lobe fruit is preferred in fresh market production and prices are generally high for good quality four lobe fruit (14). High (1, 2, 35) and low temperatures (35, 37, 42) have been reported to effect locule number. Fruits with four locules are produced when high temperatures (36$^{o}$C) occur during pre-anthesis whereas intermediate (25$^{o}$C d- 18$^{o}$C n) and low (18$^{o}$C) temperatures produce mainly three locule fruits (1, 2 42). Minges (33) wondered why there was such a big fuss over shape anyway. If you slice or dice the fruit it doesn't make any difference if the fruit has 2, 3 or 4 lobes. The only time you need nice, blocky lobe fruit is for stuffing.

## MATERIALS AND METHODS

### Greenhouse Pepper Study I

'Keystone Resistant Giant #3' green peppers (Capsicum annuum L.) pelleted seeds were sown in five cell sizes (200, 406 square plastic plug tray; 080A, 100A and 150 Todd or Speedling planter trays) (Table 1) using a peat:vermiculite commercial potting mix ("Jiffy Mix" Jiffy Products, West Chicago, Ill.) on December 10, 1987. The seeds were germinated at 26°C and under mist from 8:00 a.m. to 6:00 p.m. daily. A misting cycle of 3 seconds every 4 minutes was used. Plants were watered overhead as needed. The flats were arranged in a randomized complete block design with 4 replications.

The flats were transferred to a production greenhouse on January 4, 1988 when 75% of the seeds had germinated and were arranged in a randomized complete block design. Plants were grown at 21°C constant temperatures, watered overhead daily, and fertilized weekly with a water soluble 20 N-8.6 P-6.6 K solution at 150 ppm N.

Beginning on January 7, 1988, a 5 plant sample from each flat was measured for leaf area, shoot height, and shoot dry weight with measurements from the soil line to the meristem tip. Leaf area was measured using an electronic leaf area meter (LlCOR Model L1 3100). Plant tops were oven dried, and allowed to stand for 24 hours then weighed. Measurements were repeated at weekly intervals for six weeks.

Greenhouse Pepper Study II

Two plants from each flat were transplanted at weekly intervals into 10 cm square plastic pots filled with a 1:1:1 soil:peat:perlite by volume mix. This was done each week for 6 weeks. Shoot heights were measured and recorded as described above. The transplants were watered and fertilized using the soluble fertilizer as previously described. Pots were arranged in a randomized complete block experimental design.

At the end of each 6 weeks the 10 cm potted plants were measured for shoot height, fresh and dry shoot weight, fresh and dry root weight, and leaf area. The plants were cut off at the soil line. The shoots were weighted and leaf area measured using the LI-3100 electronic leaf area meter. The roots were washed, then weighed. Roots and shoots were bagged separately and oven dried.

Field Study

'Keystone Resistant Giant #3' green pepper (Capsicum annuum L.) pelleted seeds were sown in 4 cell sizes of flats (200 square plastic plug tray, 080 A, 100 A, and 200 Speedling planter trays) (Table 1) containing peat:vermiculite medium on March 27, 1988. The seeds were germinated at 26$^{o}$C and grown at 21$^{o}$d day and night temperatures. The flats were arranged in a randomized complete block design with 4 replications. When the leaves

appeared, the plants were fertilized as needed with soluble fertilizer as previously described.

On April 26, 1988 field plots were prepared at the KSU Horticulture Research Farm. Commercial fertilizer (13N-$13P_2O_5$-$13K_2O$) was applied and worked into the soil. The soil type was a Mollic Udiflurent (coarse-silty, mixed calcareous mesic). A side dressing of ammonium nitrate (33-0-0) at the rate of 20 kg per acre was applied on May 20, 1988. After sidedressing, Enide 90W was applied for weed control and supplemental hoeing and rototilling was done to control weeds during the growing season. Plants were sprayed for insect control as necessary.

On May 4, 1988 two plants from each flat were measured for shoot height, fresh and dry shoot weight, fresh and dry root weight, and leaf area. Measurements were taken and recorded as previously described. One-third of the plants were taken to the field plot on May 5, 1988. Five plants from each flat were transplanted (N-No holding treatment). An 18N-$46P_2O_5$-$0K_2O$ starter solution at the rate of 1.1 kg per 1132 L. was used as a starter solution.

The remaining plants were held in the greenhouse where half the flats were held at a 22$^{o}$C day and a 15$^{o}$C night temperature (C-cool holding temperature). The other half were held at 24$^{o}$C day and 18$^{o}$C night temperature (W - warm holding temperature). The flats were held at these temperatures until May 12, 1988 (one week). Two plants from

each flat in each holding treatment were then measured for shoot height, fresh and dry shoot weight, fresh and dry root weight, and leaf area. Measurements were taken and recorded as previously described. The plants were then taken to the field and transplanted. The same planting conditions as above were followed.

The field experiment was designed as a randomized complete block with 4 replications in a factorial arrangement of 4 cell sizes and 2 holding temperatures. Each plot contained 5 plants with .46 m between plants and .92 M between rows.

Flower count was recorded on June 15 and 24 and again on July 30, 1988. Flower count on June 15 and 24 was determined by the number of plants per plot that had 50% or more of the flowers fully opened. The flower count on July 30 was determined by the total number of open flowers in each plot.

Fruit was harvested weekly from July 15, 1988 to September 23, 1988. Fruit picked on July 15 and 21, 1988 were considered early, August 19, 25 and September 1 were mid, and September 8 and 23 were late. Fruit number, fresh weight, number of 4 lobe fruit, and appearance was recorded. Appearance was based on fruit characters such as color, shape, smoothness, size, firmness, and uniformity. Ratings were 1 - excellent, 2 - good, 3 - average, 4 - fair, 5 - poor.

Individual plant heights were measured in the field and recorded on September 1, 1988.

Field Experiment - Mechanical Transplanting Study

Remaining plants used in experiment II were transplanted in the field using a Model 900 mechanical transplanter on May 13, 1988. Prior to transplanting, 2 plants per flat were measured for shoot height, fresh and dry shoot weight, fresh and dry root weight. Plots were checked on May 20 and 28 for survivability of plants in each plot. On May 28, June 10, and June 24, 1988, two plants from each plot were measured for shoot height, fresh and dry shoot weight, fresh and dry root weight and leaf area. Measurements were taken and recorded as previously described.

The plots were watered as needed until June 24, 1988. Plots received the same fertilizer and herbicide treatments as the other field experiment. The experiment was a randomized complete block with 3 replications in a factorial arrangement of 4 cell sizes and 2 holding treatments. Each plot contained 20 plants with .53 m between plants and 1.83 m between rows.

Statistical Analysis

Data were analyzed by analysis of variance. Main effects in factorial experiments were separated by LSD ($p = .05$). Results from the greenhouse and field experiments were determined by regression analysis.

# RESULTS AND DISCUSSION

## Greenhouse Pepper Study I

Plants grown for a 6 week period in the 150 Speedling container produced greater shoot dry weight (Fig. 2) and leaf area (Fig. 3) than to the other flats. Plants grown in 100A flats showed a slight height difference over the 150 plug flat (Fig. 1). Plants held in the transplant container 1-3 weeks grew about the same. At the fourth week the larger container plants grew at a greater rate (Fig. 1,2,3). Generally, as the cell volume increased, plant height, dry weight, and leaf area increased. Weston (44) and others (8,47) have reported similar findings. Plants grown in the 406 plug flat showed a possible "stretching" of the plants between weeks 5 and 6. This could be due to root binding occurring in the small cell.

## Greenhouse Pepper Study II

Plant height (Fig. 4), plant dry weight (Fig. 5), root dry weight (Fig. 6), and leaf area (Fig. 7), were affected by the number of weeks the plants were grown in the various containers. Overall, the plants that were over 4 weeks old had similar or reduced plant growth. This again suggests a possible root bound condition occurred in the container. There were no differences between containers and top/root ratios in this study (Fig. 8).

Field Study

There were no difference found among container size for plant growth except for leaf area (Table 2). The leaf area increased as cell volume increased. Weston (44) and others (8,43) also reported similar results. There was also no difference found among holding treatments for plant growth except for top dry weight (Table 2). Top dry weights were greater for the treated plants ($22^{o}Cd/15^{o}Cn$, $24^{o}Cd/18^{o}Cn$) compared to the no holding treatment ($21^{o}c$). Lowering the night temperatures by a few degrees increased top growth.

Container size and holding treatments did not affect early or total seasonal yields (Table 3). Weston (43,44) reported a significant difference between container size and early yield but not total yields. Dufault and Waters (8) reported that earliness of broccoli and cauliflower was not affected by container size.

Appearance of the pepper fruit was not affected by container size or holding treatment (Table 3). Overall, the appearance was rated fair.

The percentage of 4 lobe fruit was significantly affected by container at the early and late harvests (Table 3). No differences, however, were found among the holding treatments. The 100A plants produced the highest percentage (48%) versus 27% for the 200 Speedling plug flats at the early harvest. The 200 square plug flat plants had the highest percentage at 23% compared to 5% for the 200

Speedling plug flats at the late harvest. The percent of 4 lobe fruit declined from the early to the late harvest for all container sizes. Research has shown that temperatures during early fruit development can cause a greater number of 4 lobe fruit. Temperatures of $30^{o}$-$35^{o}$d/$25^{o}$n have been shown to increase the number of 4 lobe fruit (1,2).

There were no differences among container sizes or holding treatments on early flowering (Data not shown).

## Mechanical Transplanting - Survivability Study

Plant survival was recorded on May 20 and 28, 1988 after being mechanically transplanted on May 13, 1988. There was no difference in survival rates of the plants from the four plug flats on either date (Table 4). However, plants from the 080A plug flat showed a trend toward lower survival compared to the 200 plastic plug flat which was highest. At transplanting water was applied to the plants from a tank mounted on the transplanter as the mechanical transplanter traveled down the rows. The amount of water applied to the plants in each row was determined by the transplant operator. One week after transplanting, plants were checked for moisture because of wilting of the plants since the initial watering. The soil was checked to a depth of 10 cm and found to be low in moisture. Rainfall was minimal from 13 to 28 May and temperatures ranged from lows of 15$^{o}$C to highs of 32$^{o}$C (Fig. 9).

Plants held at cool temperatures (22$^{o}$Cd/15$^{o}$Cn) had a greater survival rate on both dates (Table 4). This could be attributed to a larger root system found in plants that were held at the 22$^{o}$Cd/15$^{o}$Cn before planting. It has been shown plants with large root systems suffer less transplant shock (43, 15). This could account for the increase in the number of surviving cool temperature (22$^{o}$Cd/15$^{o}$Cn) treated plants versus the warm temperature (24$^{o}$Cd/18$^{o}$C/n) treated plants.

Plants from each plot were measured for height, top fresh and dry weight, root fresh and dry weight, and leaf area on May 28, 1988. Measurements taken on 28 May, 1988 showed significant differences among the plug flats for plant height and top dry weight but not root dry weight (Table 4). The 200 Speedling plug tray produced the most growth of any container. This is to be expected since the larger Speedling plug tray plants have been shown to have greater root mass and larger top fresh and dry weights and leaf areas (8, 43, 44). Measurements taken June 10, 1988 showed significant differences in height only (Table 4). The 200 plastic plug tray and Speedling 100 plug tray showed the greatest height compared to the Speedling 080A and Speedling 200 plug tray. The Speedling 200 plug tray showed greater top fresh weight, top dry weight, and root fresh weight, as compared to the other plug flats. There was no difference in size among the plants measured on June 24, 1988 (Table 4). Little significance was found between plants held at warm and or cool temperatures. The $22^{o}C/15^{o}C$ holding treatment did however produce plants with a trend for slightly higher height, top fresh weight, top dry weight, root fresh weight, root dry weight, and leaf area (Table 4).

Another problem with mechanical transplanting is size of the plant top. If plants have large top growth they may hang up in the planter mechanism. The plant cannot drop

out of the holder and the top can be crushed. One must then remove the damaged plant and replace it with a new plant. By this time several skips occur in the row. The 200 plastic plug and the 100 Speedling plug seemed to be the easiest to use for mechanical transplanting due to the smaller size and more compact nature of the plant.

## CONCLUSION

Plant Study I shows that container sizes did affect the growth of pepper plants. As cell volume increased, plant growth increased.

Plant Study II showed that plant growth was affected by the number of weeks plants were grown in the containers. Plants that grew in the containers for more than 4 weeks had similar or reduced growth.

The field study showed that container sizes and holding temperatures had no affect on appearance, early and total yields.

Plants held at $22^{\circ}$ d/$15^{\circ}$C n had a higher survivability rate when mechanically transplanted than plants held at $24^{\circ}$ d/$18^{\circ}$C n.

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Table 1. Spatial and economic characteristics of various container sizes.

| Container type | Width (cm) | Depth (cm) | Plant density (plants/$m^2$)[z] | Volume ($cm^3$) | Cost: Plant (¢) | Cost: Hectare[y] ($) |
|---|---|---|---|---|---|---|
| 406 sq. plastic | 1.2 | 1.5 | 2594 | 2.0 | -- | -- |
| 200 sq.plastic | 2.0 | 3.0 | 1278 | 6.0 | -- | -- |
| 080A Spd. | 2.0 | 4.5 | 1450 | 5.9 | 1.9 | 454 |
| 100 Spd. | 2.8 | 7.2 | 858 | 18.6 | 2.7 | 645 |
| 150 Spd. | 3.8 | 6.4 | 528 | 30.5 | 4.5 | 1075 |
| 200 Spd. | 5.1 | 7.0 | 295 | 78.0 | 8.0 | 1912 |

[z]1988 prices from Speedling, Inc., Sun City, Fla. Speedling does not sell 200 or 406 sq. plugs. No current prices for 200 or 406 sq. plugs.

[y]Based on 23,909 plants/ha (0.46 between plants and .92 m between rows).

Table 2. Initial size for pepper transplants grown in several containers and holding treatments.

| Container | Plant ht (cm) | Top dry wt/plant (gm) | Root dry wt/plant (gm) | Leaf area/plant (cm) |
|---|---|---|---|---|
| 200 sq. plastic | 14.63 | 1.13 | 0.31 | 158 |
| 080A Speedling | 11.35 | 0.89 | 0.23 | 139 |
| 100A Speedling | 12.00 | 1.50 | 0.28 | 181 |
| 200 Speedling | 14.00 | 1,23 | 0,36 | 317 |
| Mean | 12.9 | 1.19 | ,29 | 198. |
| Holding | | | | |
| 24/18°C - 1 wk | 16.3 | 1.43 | 0.23 | 218 |
| 22/15°C - 1 wk | 13.7 | 1.45 | 0,36 | 229 |
| LSD 0.05 | NS | NS | NS | NS |

LSD .05 level of significance or NS - non significant

Table 3. Effect of containers and holding treatments on yield and appearance of 'Keystone Resistant Giant #3 green pepper transplants (mean of 2 plants per experimental unit, 4 replications).

| | Fruit yield (kg/plant)[x] | | | | Appearance[y] | | | % 4 lobe | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Container | Early | Mid | Late | Total | Early | Mid | Late | Early | Mid | Late |
| 200 sq. plastic | 0.24 | 1.53 | 0.44 | 2.17 | 3.2 | 3.1 | 3.6 | 24.3 | 19.0 | 23.0 |
| 080A | 0.26 | 1.57 | 0.32 | 2.16 | 2.8 | 3.6 | 3.6 | 30.8 | 21.9 | 20.2 |
| 100A | 0.28 | 1.60 | 0.39 | 2.27 | 3.0 | 3.5 | 3.5 | 48.6 | 22.5 | 17.9 |
| 200 | 0.32 | 1.56 | 0.42 | 2.28 | 2.8 | 3.5 | 3.5 | 27.8 | 22.9 | 5.0 |
| LSD 0.05 | NS | NS | NS | NS | NS | NS | NS | 22.7 | NS | 8.8 |
| Holding | | | | | | | | | | |
| Not held | 0.25 | 1.67 | 0.45 | 2.43 | 3.1 | 3.5 | 3.5 | 39.8 | 29.4 | 19.2 |
| 24/18°C-1 wk | 0.25 | 1.51 | 0.30 | 2.08 | 2.8 | 3.5 | 3.5 | 35.2 | 22.7 | 15.2 |
| 22/15°C-1 wk | 0.25 | 1.22 | 0.42 | 2.17 | 2.8 | 3.7 | 3.7 | 23.43 | 24.85 | 15.0 |
| LSD 0.05 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

[x] Early represents 15, 21, 28 July, 1988, mid - 19, 25 Aug, 1 Sept, 1988, Late - 8, 23 Sept, 1988.

[y] Appearance based on fruit characteristics: color, shape, smoothness, size, firmness, and uniformity. 1 - excellent to 5 = poor.

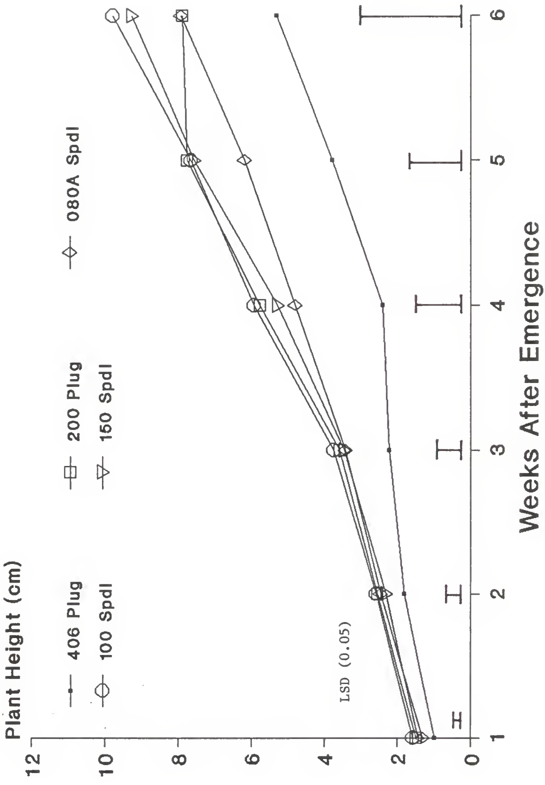
LSD .05 level of significance or NS - non significant.

Table 4. Survival and growth rates of mechanically transplanted 'Keys Resistant Giant #3' green pepper plants grown in various transplant containers and using two holding treatments. (mean of 2 plants/experimental unit, 3 replications)

| | Survival | | May 28 | | | June 10 | | | June 24 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Container type | 20 May'88 (%) | 28 May'88 (%) | HT. (cm) | TDW (gm) | RDW (gm) | HT. (cm) | TDW (gm) | RDW (gm) | TDW (gm) | RDW (gm) |
| 200 sq. plug | 94 | 89 | 12.13 | 2.67 | 1.22 | 15.68 | 3.75 | 2.80 | 53.68 | 5.93 |
| 080 A Spd | 78 | 72 | 9.66 | 1.42 | 0.70 | 10.93 | 2.67 | 1.84 | 45.93 | 6.50 |
| 100A Spd | 90 | 89 | 13.23 | 2.79 | 1.04 | 15.40 | 4.06 | 2.74 | 52.00 | 9.28 |
| 200 Spd | 92 | 90 | 12.74 | 2.31 | 1.17 | 14.18 | 4.27 | 1.70 | 63.92 | 7.76 |
| LSD 0.05 | NS | NS | 1.8 | .75 | NS | 2.06 | NS | NS | NS | NS |
| <u>Holding</u> | | | | | | | | | | |
| 24/18°C-1 wk | 82 | 79 | 11.65 | 2.30 | 1.01 | 13.81 | 3.65 | 2.10 | 47.39 | 7.03 |
| 22/15°C-1 wk | 95 | 91 | 12.24 | 2.69 | 1.04 | 14.28 | 3.73 | 2.43 | 60.40 | 7.70 |
| LSD 0.05 | 9.7 | 10.1 | NS | NS | NS | NS | NS | | NS | NS |

LSD .05 level of significance or NS - Nonsignificant

Figure 1. The effect of various transplant containers on plant height of 'Keystone Resistant Giant #3' pepper plants grown for 6 weeks after emergence.



Plant Height (cm)
406 Plug
100 Spdl
200 Plug
150 Spdl
080A Spdl
LSD (0.05)
0
2
4
6
8
10
12
1
2
3
4
5
6
Weeks After Emergence

Figure 2. The effect of various transplant containers on dry weight of 'Keystone Resistant Giant #3' pepper plants grown for 6 weeks after emergence.

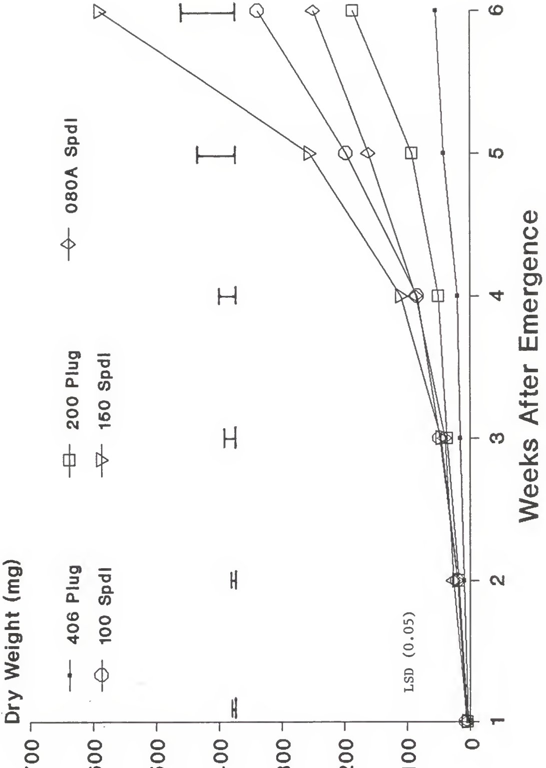

Dry Weight (mg)
406 Plug
100 Spdl
200 Plug
150 Spdl
080A Spdl
LSD (0.05)
0
100
200
300
400
500
600
700
1
2
3
4
5
6
Weeks After Emergence

Figure 3. The effects of various transplant containers on leaf area of 'Keystone Resistant Giant #3' pepper plants grown for 6 weeks after emergence.

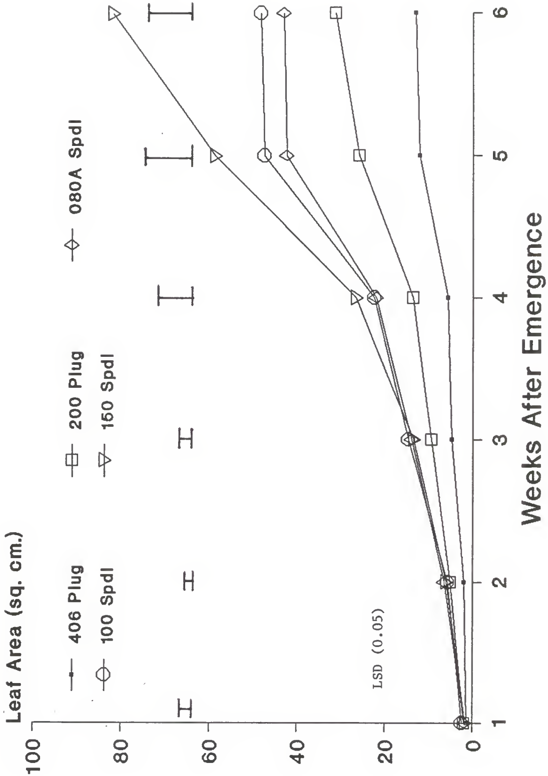
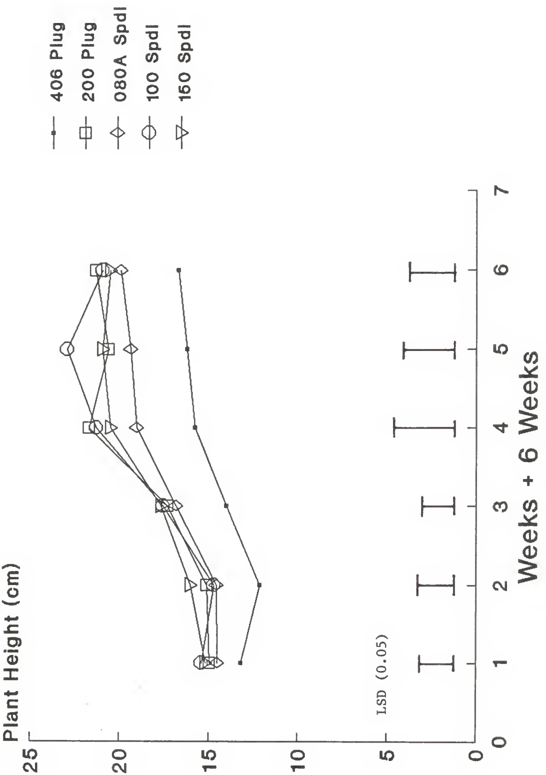

Leaf Area (sq. cm.)
406 Plug
200 Plug
080A Spdl
100 Spdl
150 Spdl
LSD (0.05)
100
80
60
40
20
0
1
2
3
4
5
6
Weeks After Emergence

Figure 4. The effect of various transplant containers on plant height of 'Keystone Resistant Giant #3' pepper plants grown for 1 to 6 weeks in the container then transplanted into 10 cm plastic pots for 6 additional weeks.



Plant Height (cm)
25
20
15
10
5
0
LSD (0.05)
0
1
2
3
4
5
6
7
Weeks + 6 Weeks
406 Plug
200 Plug
080A Spdl
100 Spdl
150 Spdl

Figure 5. The effect of various transplant containers on plant dry weight of 'Keystone Resistant Giant #3' pepper plants grown from 1 to 6 weeks in the container then transplanted into 10 cm plastic pots for 6 additional weeks.

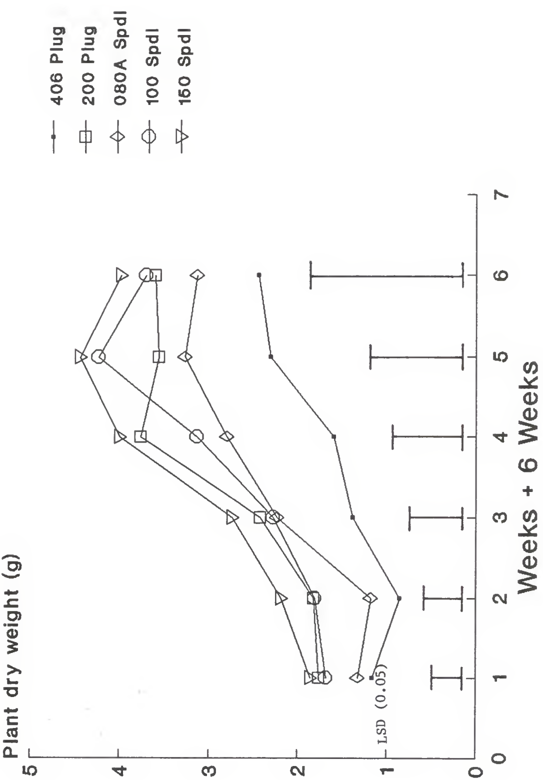
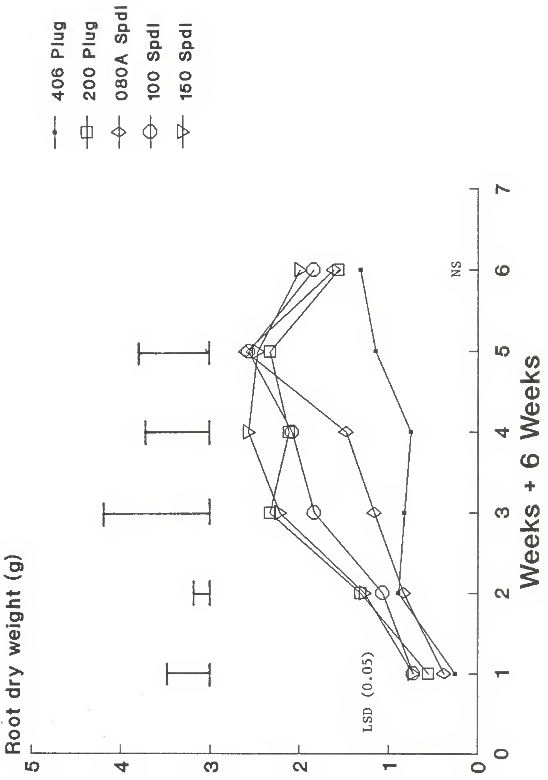
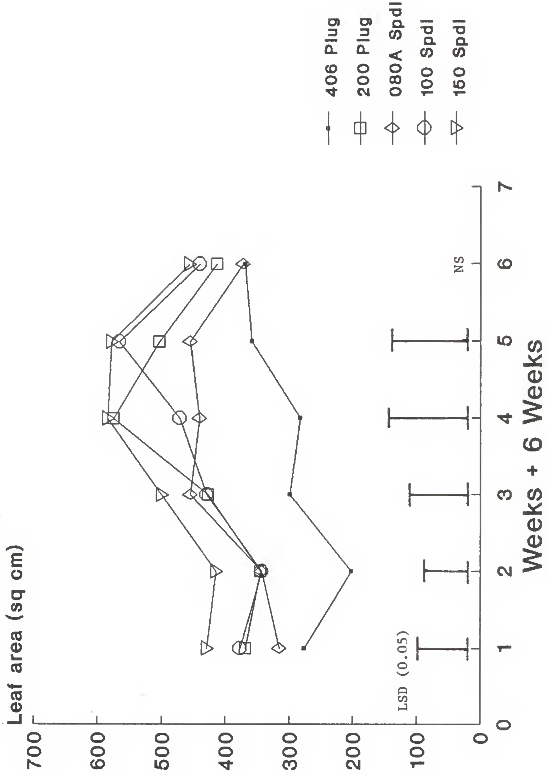

Plant dry weight (g)
Weeks + 6 Weeks
LSD (0.05)
406 Plug
200 Plug
080A Spdl
100 Spdl
150 Spdl
0
1
2
3
4
5
6
7

Figure 6. The effect of various transplant containers on root dry weight of 'Keystone Resistant Giant #3' pepper plants grown from 1 to 6 weeks in the containers then transplanted into 10 cm plastic pots for 6 additional weeks.



Root dry weight (g)
0
1
2
3
4
5
LSD (0.05)
NS
0
1
2
3
4
5
6
7
Weeks + 6 Weeks
406 Plug
200 Plug
080A Spdl
100 Spdl
150 Spdl

Figure 7. The effect of various transplant containers on leaf area of 'Keystone Resistant Giant #3' pepper plants grown from 1 to 6 weeks in the container then transplanted to 10 cm plastic pots for 6 additional weeks.



Leaf area (sq cm)
700
600
500
400
300
200
100
0
LSD (0.05)
NS
0
1
2
3
4
5
6
7
Weeks + 6 Weeks
406 Plug
200 Plug
080A Spdl
100 Spdl
150 Spdl

Figure 8. The effect of various transplant containers on top/root ratio of 'Keystone Resistant Giant #3' pepper plants grown from 1 to 6 weeks in the container then transplanted to 10 cm plastic pots for 6 additional weeks.

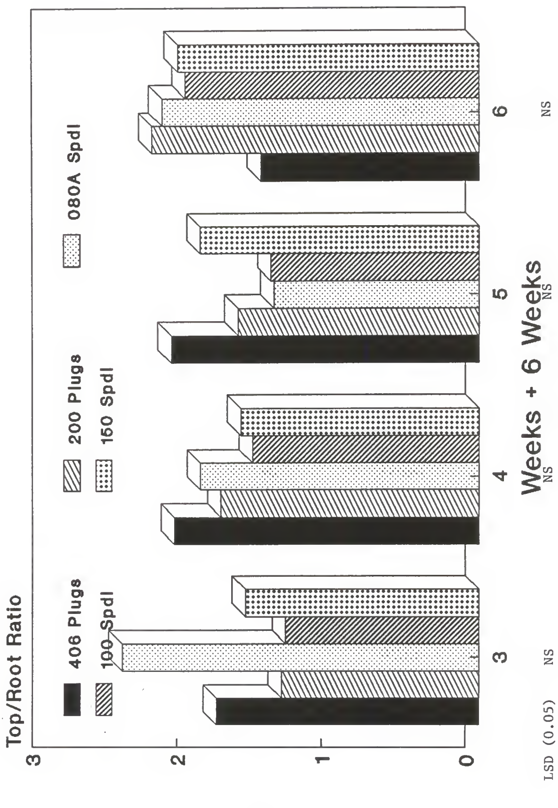
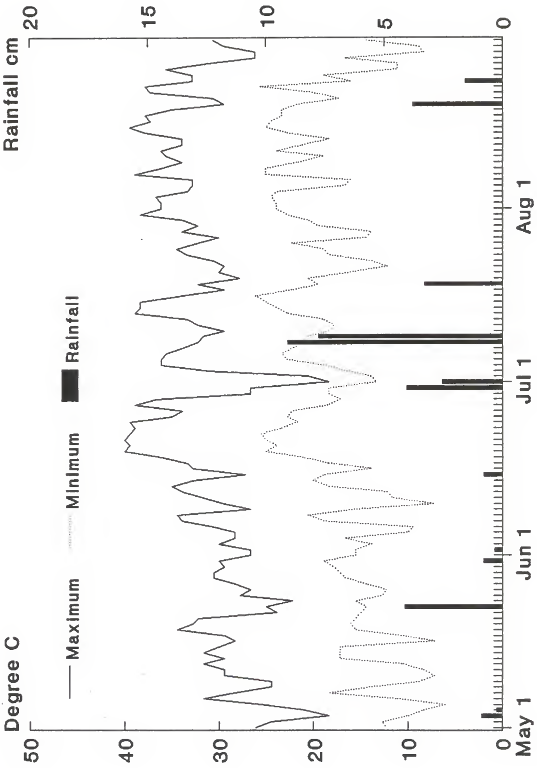

Top/Root Ratio
3
2
1
0
406 Plugs
100 Spdl
200 Plugs
150 Spdl
080A Spdl
3
4
5
6
Weeks + 6 Weeks
LSD (0.05)
NS
NS
NS
NS

Figure 9. Climatic data for Manhattan, May to August, 1988.


Degree C
Maximum
Minimum
Rainfall
Rainfall cm
50
40
30
20
10
0
20
15
10
5
0
May 1
Jun 1
Jul 1
Aug 1

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# STUDIES OF CONTAINER SIZE AND TYPE FOR PEPPER (_Capsicum annuum_ L.) TRANSPLANT PRODUCTION

by

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B.S., Kansas State University, 1977

AN ABSTRACT OF A THESIS

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ABSTRACT

'Keystone Resistant Giant #3' pepper (<u>Capsicum</u> <u>annuum</u> L.) seeds sown in five cell sizes were compared for growth rates among container cell sizes. Transplants grown in the Speedling cell size 150 (30.5 $cm^3$) produced greater shoot dry weight and leaf area than the smaller containers. Plants grew at the same rate for the first 3 weeks, but by week 4, plant growth rate was related to container volume. Transplants were set at weekly intervals into 10 cm plastic pots to compare plant growth after an additional 6 week growth period. Plant height, plant dry weight, root dry weight, and leaf area increased for plants held week 1-3 but remainned constant or decreased week 4-6.

Pepper transplants from four cell sizes were transplanted in the field to compare yield, fruit shape (4 lobe fruit), appearance and mechanical transplanting survivability. Plants were held at two different temperature treatments; $22^oCd/15^oCn$, and $24^oCd/18^oCn$ for one week before hand and mechanical transplanting. Container cell size did not affect early or total seasonal yields of peppers. Transplants grown in the 100A Speedling cell size (18.6 $cm^3$) produced the largest percentage of 4 lobe fruit. Transplants held at $22^oCd/15^oCn$ had the greatest survival rate in the mechanically transplanted pepper plants.